Lecture 1

Introduction

Fundamentals of Computer and Programming

Instructor: Morteza Zakeri, Ph.D. (m-zakeri@live.com)

Spring 2024

Modified Slides from Dr. *Hossein Zeinali* and *Dr. Bahador Bakhshi*

Computer Enginnering Department, Amirkabir University of Technology

What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems

This Course

- Introduction to Computer & Programming

How to use computers to solve our problems

- The problems are *computational* problems

This Course (cont'd)

- What we learn
  - Overall overview of computer organization
  - Problem solving steps
    - Algorithm design
    - A programming language: the C
- What we don't learn
  - In depth computer hardware/software details
  - Most advanced algorithms
  - System programming using C
  - Other programming languages: Java, PHP, …

CA, OS, …

Alg, DS, …

OS, …

AP, IE, …

This Course (cont'd)

- Steps to learn a new language (English, French, … C, Java, Python, …)
  - Present: what is the new language (course slide)
  - Practice: how to use the new language in practice (the example)
  - Produce: use the language to create a new things (Lab, HW)
- Learning Programming Language
  - is not a pure theoretical course (mathematics, …)
    - Reading, reading, reading, ….
  - is a practical course needs the product step
    - Class, Reading, programming, programming, programming,…

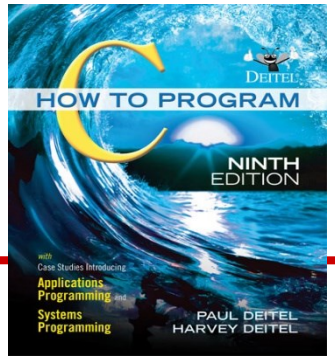
This Course (cont'd)

- Course materials
  - Lecture notes (slides) are in (**simple**) English
  - Available in the course homepage:

    https://m-zakeri.github.io/CP/

  Textbook:

  - **C: How to Program 9th Edition** (2022)
  - **https://deitel.com/c-how-to-program-9-e/**
  - **https://github.com/pdeitel/CHowToProgram9e**



C How to Program, Ninth Edition

with Case Studies Introducing Applications Programming and Systems Programming

by Paul Deitel & Harvey Deitel

PART 1 (Introductory) Programming Fundamentals Quickstart

1. Introduction to Computers and C
Intro to Hardware, Software & Internet; Test-Drive Microsoft Visual Studio, Apple Xcode, GNU gcc & GNU gcc in Docker

2. Intro to C Programming
Input, Output, Types, Arithmetic, Decision Making, Secure C

3. Structured Program Development
Algorithm Development, Problem Solving, `if`, `if/else`, `while`, Secure C

4. Program Control
`for`, `do/while`, `switch`, `break`, `continue`, Logical Operators, Secure C

5. Functions
Custom Functions, Simulation, Random-Number Generation, Enumerations, Function Call and Return Mechanism, Recursion, Recursive Factorial, Recursive Fibonacci, Secure C

- C is one of the world's most popular and senior programming languages
- C18/C11 standards
- Topical, innovative presentation
- Rich coverage of fundamentals
- Problem-solving/developing algorithms
- 20+ fun computer-science, data-science and artificial-intelligence case studies show C as it's intended to be used—some are fully implemented, some are partially implemented and some require students to do online research
- 147 complete working programs
- 350+ integrated self-check exercises with answers
- 445 end-of-chapter exercises/projects
- Use with Windows®, macOS®, Linux®
- Visual C++®, Xcode® and GNU™ gcc

PART 2 (Intermediate) Arrays, Pointers and Strings

6. Arrays
One- & Two-Dimensional Arrays, Passing Arrays to Functions, Searching, Binary Search Visualization, Sorting, Secure C

7. Pointers
Pointer operators & and *, Pass-By-Value vs. Pass-By-Reference, Array and Pointer Relationship, Secure C

8. Characters and Strings
C Standard Library String- and Character-Processing Functions, Secure C

PART 3 (Intermediate) Formatted Input/Output, Structs and File Processing

9. Formatted Input/Output
`scanf` and `printf` formatting, Secure C

10. Structures, Unions, Bit Manipulation and Enumerations
Creating Custom Types with `structs` and `unions`, Bitwise Operators, Enumeration Constants, Secure C

11. File Processing
Streams, Text and Binary Files, CSV Files, Sequential and Random-Access Files, Secure C

- Analysis of algorithms with Big O
- Enhanced security and data science coverage as per ACM/IEEE 2020 curricula recommendations
- Use free open-source libraries and tools
- Real-world examples and data
- Traditional or "flipped" classrooms
- Secure C Programming, privacy, ethics
- Case studies in systems programming and applications programming
- Think like a developer with GitHub®, open-source, StackOverflow and more

PART 4 (Advanced) Data Structures and Algorithms

12. Data Structures
Dynamic Memory Allocation, Lists, Stacks, Queues & Binary Trees, Secure C

13. Computer-Science Thinking: Sorting Algorithms and Big O
Insertion Sort, Selection Sort, Visualizing Merge Sort, Additional Algorithms including Quicksort in the Exercises

PART 5 (Advanced) Preprocessor and Other Topics

14. Preprocessor
`#include`, Conditional Compilation, Macros/Arguments, Assertions, Secure C

15. Other Topics
Variable-Length Argument Lists, Command-Line Arguments, Multiple-Source-File Programs, `extern`, `exit`/`atexit`, `calloc`/`realloc`, `goto`, Numeric Literal Suffixes, Signal Handling

Appendices

A. Operator Precedence
B. ASCII Character Set
C. Multithreading/Multicore and Other C11/C18 Topics
D. Intro to Object-Oriented Programming

Online Appendices

E. Number Systems
F–H. Using the Visual Studio, GNU gdb and Xcode Debuggers

- Emphasis on visualization
- Static code analysis tools
- Performance, multithreading, multicore
- Questions? `deitel@deitel.com`
- Updates and errata: `https://deitel.com/chtp9`

Systems Programming Case Studies

Systems Software
- Building Your Own Computer
- Building Your Own Compiler with Infix and Postfix Notation

Embedded Systems Programming
- Webots 3D Robotics Simulator

Performance: Threading/Multicore

Applications Programming Case Studies

Algorithm Development
- Counter-Controlled Iteration
- Sentinel-Controlled Iteration
- Nested Control Statements

Random-Number Simulation
- Building a Casino Game
- Card Shuffling/Dealing with Card Images
- The Tortoise and the Hare Race

Intro to Data Science
- Data Analysis: Mean, Median & Mode

Direct-Access File Processing
- Transaction-Processing System

Visualizing Searching & Sorting

Artificial Intelligence/Data Science
- Machine Learning, GNU Scientific Library, Plotting with gnuplot, CSV Files
- NLP: Who Wrote Shakespeare's Works?

Game Programming with raylib
- SpotOn and Cannon Games

Security Via Cryptography
- Secret-Key & RSA Public-Key Crypto

Visualization with raylib
- Law of Large Numbers Animation

Multimedia: Audio & Animation

Web Services, Mashups, Cloud
- Accessing Web Services with libcurl; OpenWeatherMap JSON Results
- Rapid Applications Development with Web-Service Mashups

Who Am I?

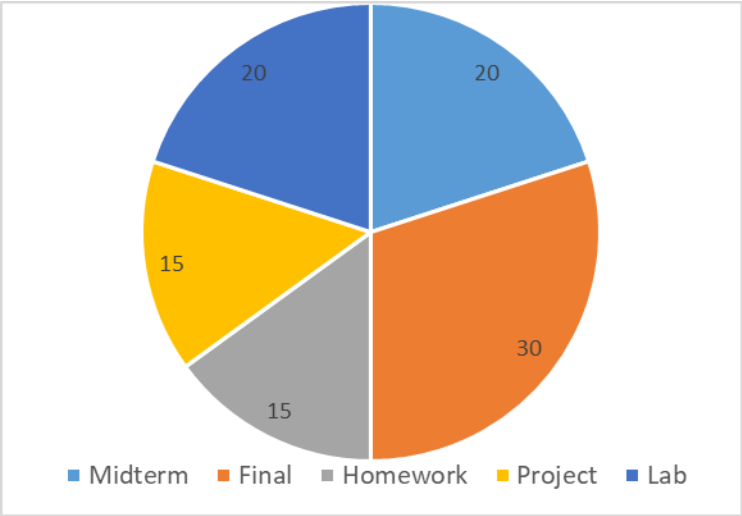
- Morteza Zakeri
  - Ph.D. in Computer Engineering
    - Software Engineering Major
    - Iran University of Science and Technology
  - Interested in intelligent software engineering, compilers, refactoring, and program analysis.
  - More info: *https://m-zakeri.github.io*

How Can You Find Me?

- At the department
  - After each class session.
- Email:
  - m-zakeri@live.com
- Skype ID:
  - zakerim2012
- Telegram ID:
  - @mztel

Grading policy and Extra Classes

- Five major parts
  - I. Midterm 20% (4 of 20)
  - II. Final 30% (6 of 20)
  - III. Homework 15% (3 of 20)
  - IV. Project 15% (3 of 20)
  - V. Lab 20% (4 of 20)



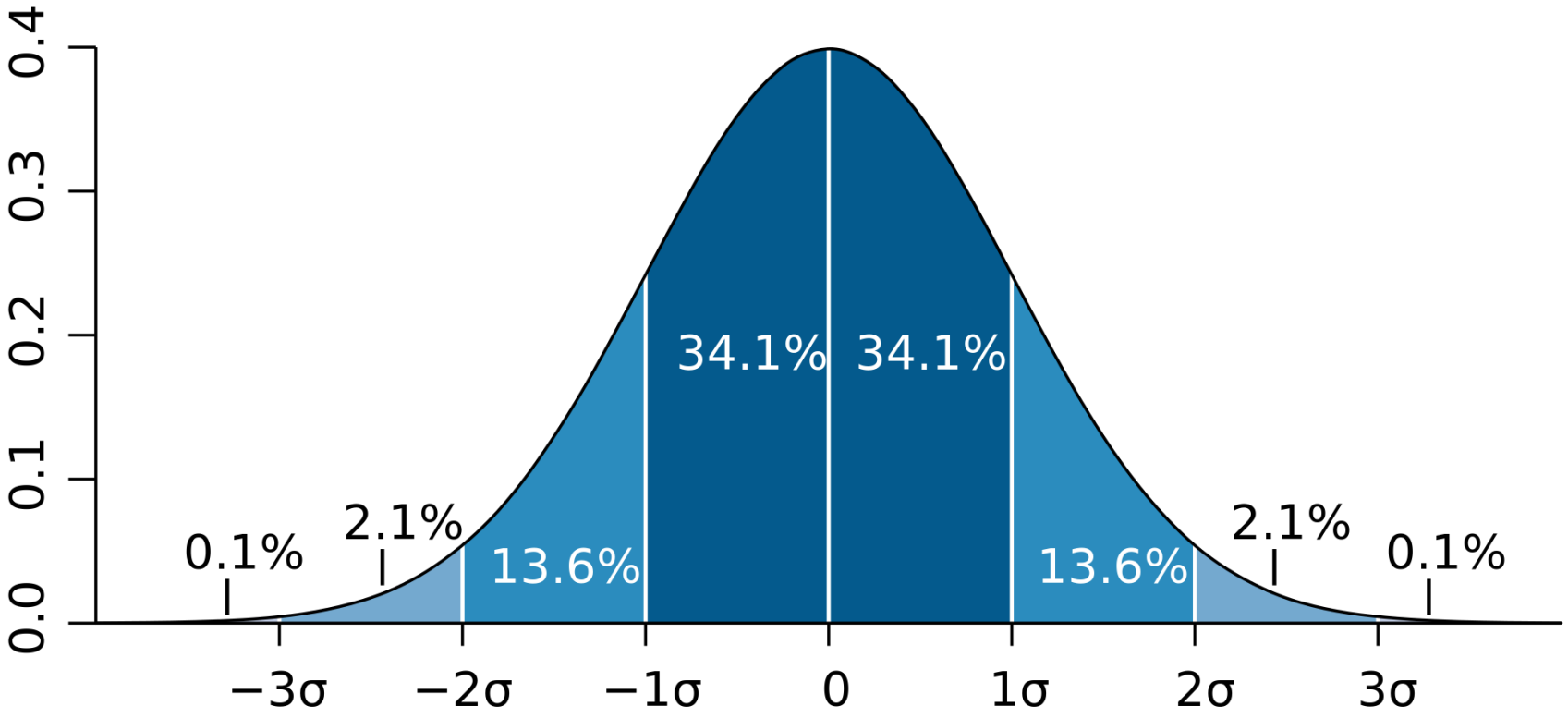
- Lab + TA Classes
  - Lab: A practical class with writing reports, **Mandatory**
  - TA: More details, practical aspects, solving HW, etc.
    - At least **4 sessions** must be attended.
    - Homework is not accepted after solutions.

Who Will Pass the Course?

- Get **4** out of 10 marks from both exams
- Get **8** out of 17 marks from the exams, lab, and the project
  - The homework grades will **not pass you!**
- There are bonuses in different parts of the course
  - Only for those that have an **acceptable correlation** between homework and other parts of the course!

The Normal Distribution

Typically your grades follows …



Any Question?!

- Is CE a good dep. of the university?! Yes ☺
- Is AUT really a top university?! Yes ☺
- Will I be wealthy as a Computer Engineer?! Yes ☺
- Do I need to learn C?! Yes!!! ☺
- Is CE a simple and easy-going? No ☺
- Is the internet free at the university?! Yes ☺
- Is lunch free?! No ☹
- …

What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems

Computers: The *Computing* Machines

- Computers classification:
  - Supercomputers
    - Weather forecast, Large scale simulation, …
  - Mainframe computers
    - The servers in large companies: Google, …
  - Midsize computers
    - The servers in CE department
  - Micro computers (also called PC)
    - Our laptop
  - Pocket PCs
    - Our mobile phones

Computers

- Computers are anywhere, anytime. Why?
  - They can solve many different problems. How?
- Computers are *programmable machines* capable of performing calculations (computation)
  - Changing program leads to different operation
- *Special-purpose* machines
  - Calculators, game-playing machines, …
- *General-purpose* computers
  - Personal computers, notebooks, …

Data Units

- Computers are digital machines
- Data processed or stored in computer is represented as two-state values
  - either 1 or 0 - BInary digiTs (BIT)
  - 1 Byte = 8 bits
  - 1 kilobyte (KB) = 1024 bytes
  - 1 megabyte (MB) = 1024 kilobyte
  - 1 gigabyte (GB) = 1024 megabyte

Data Representation/Coding

- How to represent our data by 0-1?
- In other word, there are some 0 and 1 in the computer, what is the meaning?

Coding (Representation Standards)

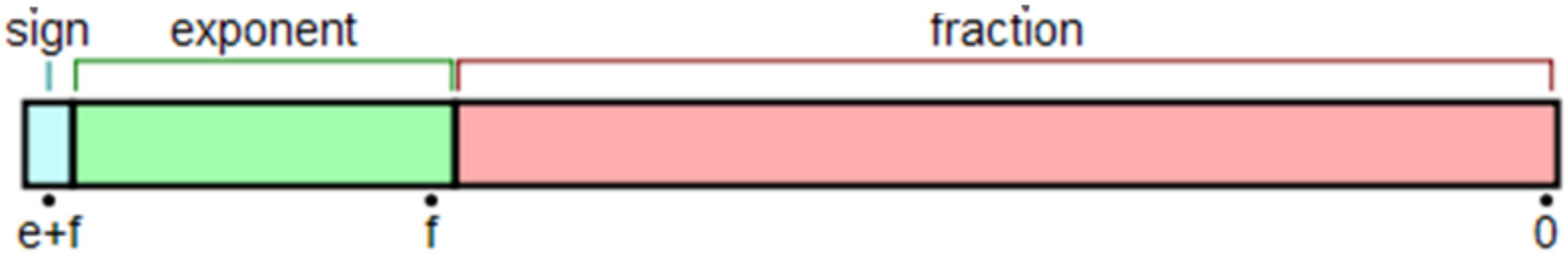
- Major (common) representations (coding)
  - Integer numbers: 1, 1000, -123, 0, …
  - Floating point numbers: 1.1, 11.232, -12.23, …
  - Characters: ‘A’, ‘ب’, ‘@’, …

Integer Number Coding

- There are different representations
  - You will learn them (in details) in other courses (*e.g.* Computer Architecture)
- One of the (simple) coding is sing-magnitude coding
  - If we have n bit for coding integers
    - The left bit (the MSB): sign
    - n-1 bits: magnitude
  - E.g., 8 bit for coding
    - 4 → 00000100 -4 → 10000100
    - 0 → 00000000 -0 → 10000000 :-P :-D

Floating Point Number Coding

- Usually, this coding pattern (IEEE 754)



- You will see all details in other courses
- Two precisions
  - Single precision
    - exponent: 8 bit, fraction: 23 bit
  - Double precision:
    - exponent: 11 bit, fraction: 52 bit

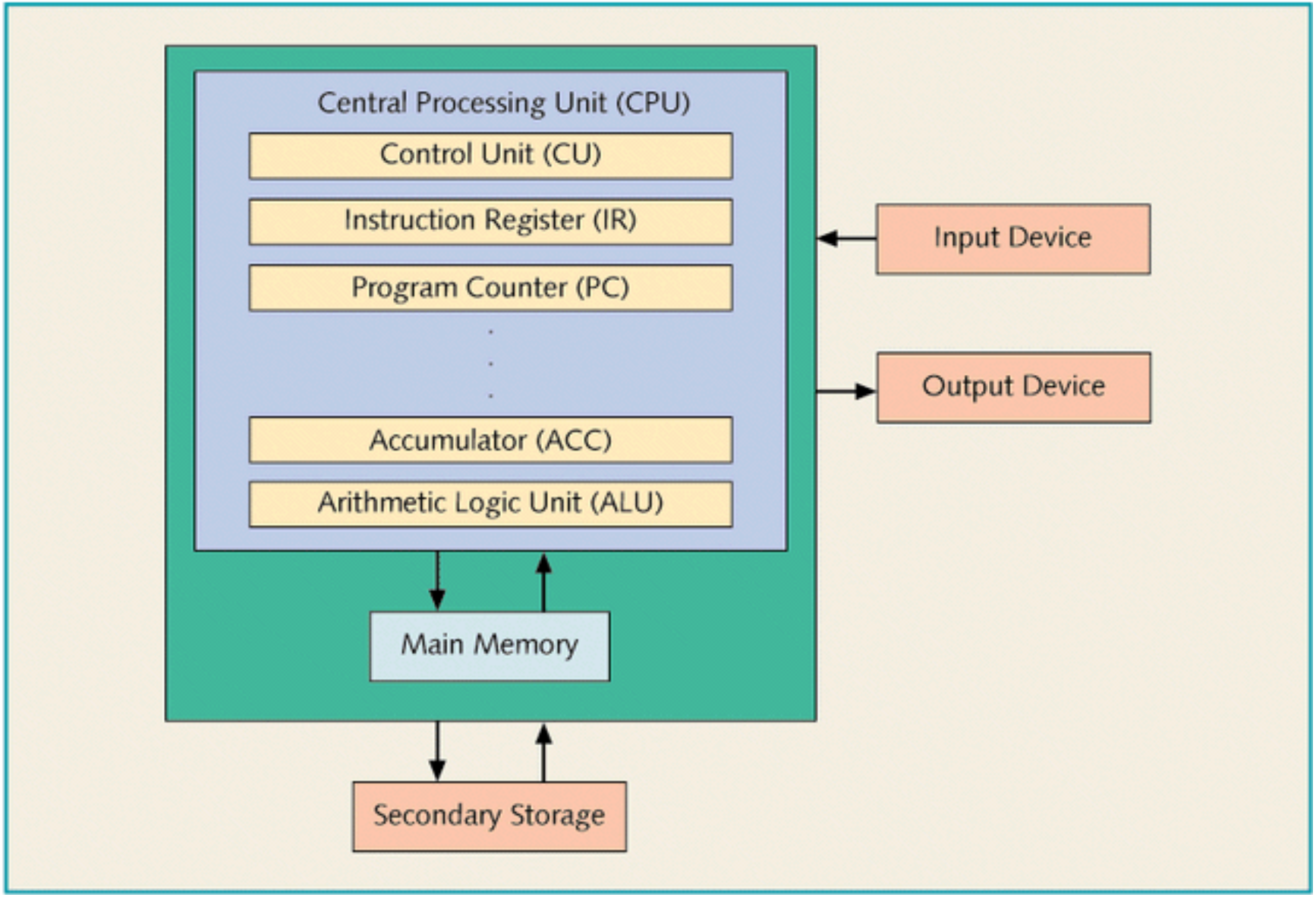
Character Coding

- Common character encoding: ASCII
  - Character ASCII Code Binary (8 bit)
  - '0' 48 00110000
  - 'A' 65 01000001
- 8 bits can represent 256 characters; but,
  - There are so many characters (Farsi, Arabic, …)
  - Solution: UTF (Variable length coding)
    - 0xxxxxxx: 1 byte code
    - 110xxxxx 10xxxxxx: 2 byte code
    - …

Computer Organization

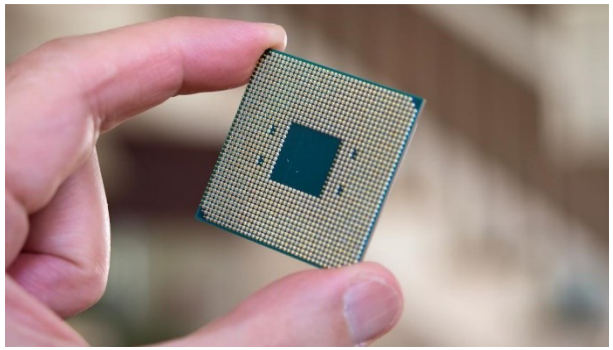
- Major Components
  - Hardware
    - *Physical devices* that are *wired* and performs *basic* operations
  - Software
    - Set of *programs* that run on the hardware
- Hardware
  - CPU (Central Processing Unit)
  - Main Memory
  - Secondary Storage
  - Input/output

Computer Organization



Computer Organization: CPU

- ALU (Arithmetic Logic Unit)
  - Performs mathematic calculations
  - Makes decision based on conditions
- Special Floating Point processors
- Set of working area: Registers
- Control Unit
  - Controls system operation



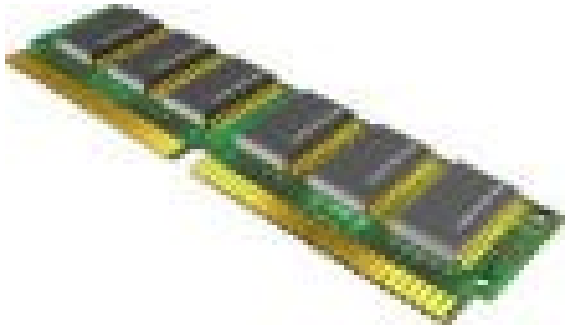
- Operation and operands are required
  - Which are provided by instructions in the main memory

Computer Organization: Main Memory

- Ordered sequence of cells (memory cells)
- Directly connected to CPU
- All programs must be in main memory before execution
- When power is turned off,

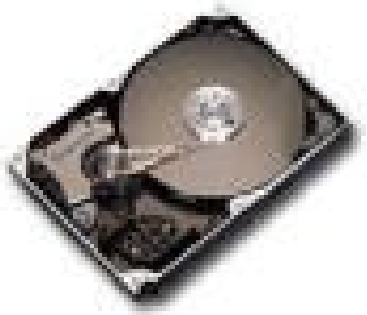
  Main memory is cleared

  Volatile memory



Computer Organization: Secondary Storage

- Provides permanent storage for information
- Examples of secondary storages:
  - Hard Disks
  - Floppy Disks
  - Flash/Cool/USB Disks
  - CD/DVD
  - Tapes



Computer Organization: Input Devices

- Devices that feed data and programs into computers
- Examples:
  - Keyboard
  - Mouse
  - Network Interface Card
  - Joystick
  - Microphone

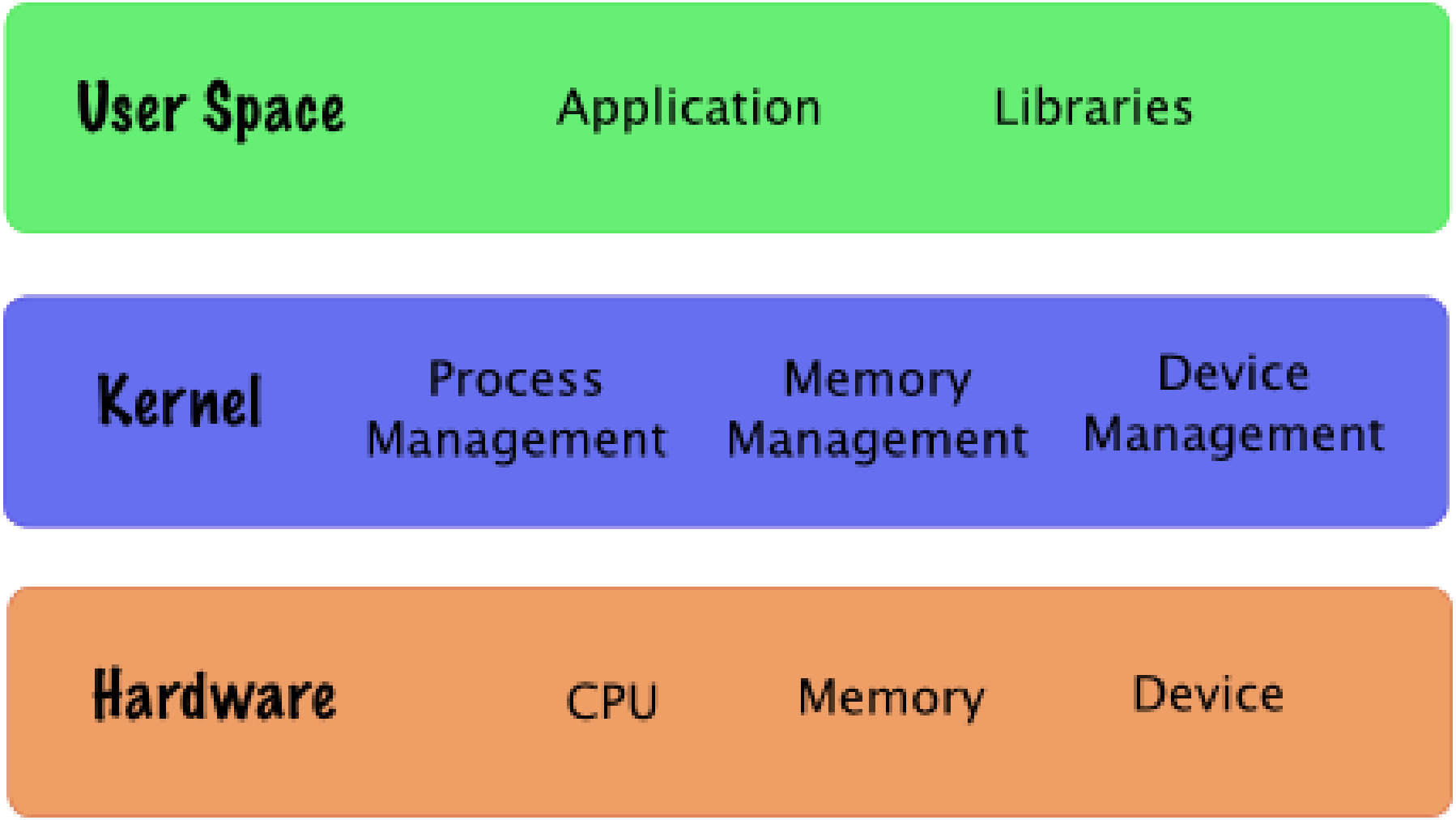
Computer Organization: Output Devices

- Devices that computer uses to generate results/outputs
- Examples:
  - Printer
  - Monitor
  - Speaker
  - Network Interface Card

Computer Organization: Software

- What can do the Hardware?
  - No useful operation, if there isn't any software
  - We should *tell/plan/program* it to do something
- Software
  - Programs which are designed for a specific task
- Major Software types
  - Operating System
  - Libraries
  - Applications (To be studied in this course)

Computer HW & SW Organization



Computer Organization: OS

- OS
  - *Manages* the hardware
    - HW is a shared resources
  - Application programmers can easily use HW
    - *Without knowing the HW details*
- Common operating systems
  - Unix, Windows (XP, Vista, 8, 10, 11), Linux, …

Computer Organization: Libraries

- The libraries provide the most common functionalities
- In mathematic programs
  - *sin*(x), *cos*(x), matrix multiplication/inversion
- In graphical programs
  - Draw a line/cycle, set color, new window
- In multimedia programs
  - Open/close files, jump, …

Computer Organization: Applications

- An application program
  - Users use them to do some specific things
  - *Without knowing the details of the computer*
- Common application programs
  - *Word*, *Internet Explorer*, *FireFox, Messengers*
- Common applications in mathematic:
  - *Matlab, Mathematica, Maple, GAMS, AIMMS*

Programming Execution Phases

- Program is loaded from secondary storage to main memory by OS (loader)
- OS gives the control to the program
- Instructions run
- Required inputs are got from input device & saved in main memory & used by CPU
- Result is saved in main/secondary memory or sent to output devices

Instruction Execution Steps

- Basic steps in running instructions
- Read instruction from main memory: fetch
  - `"000110…011"`
- Decode the instruction
  - `add 1 to memory location XYZ save result in ABC`
- Get required operands from main memory
  - `Read value of location XYZ to temp1`
- Run the instruction
  - `temp2 = temp1 + 1`
- Save the result
  - `Write temp2 in memory location ABC`

How to be general purpose machine?

- Hardware is simple & general purpose
  - Only a small set of basic instructions (+, -, *, …) are implemented by hardware
- Complex tasks (*e.g.* average, sort, …) are programmed by software
  - Basic instruction and high-level complex instructions
- Software is translated to the basic instructions
  - Hardware can run it
- This is the way that we "*program*" computers

Reference

- Reading Assignment: Chapter 1 and Appendix C of “C How to Program”
- Learn more about computer hardware
  - “How Computers Work”

What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems

Algorithm??!!!

- Hardware do the basic operations
- We want to solve a real problem by computers
  - Take average, Sort, Painting, Web, Multimedia, …
- We need a solution that
  - Specifies how the real (complex) problem should be solved *step-by-step* using the basic operations
- The solution is the "**Algorithm**" of the problem

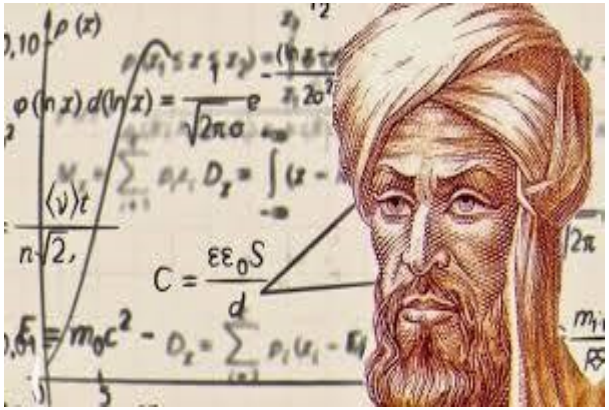
Algorithms (cont'd)

- Common Sense (in computer science):
  1) The way to do some things
  2) An abstract way to solve a problem
- Formal Definition:

"*An algorithm is a finite list of well-defined instructions for accomplishing some task that, given an initial state, will proceed through a well-defined series of successive states, possibly eventually terminating in an end-state*"

Algorithms: Examples

- Finding Common Divisor
- Finding 2 largest element in a set
- Finding shortest path in a graph
- Searching in a sorted array
- Sorting a set
- Combining 2 sorted set in a sorted set
- Solving an equation
- Compression algorithms
- Cryptography algorithms
- ….



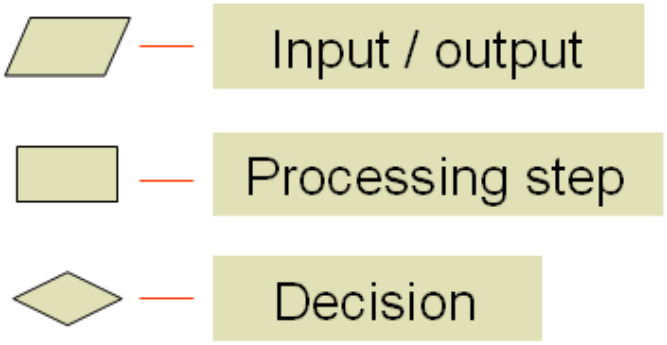
al-Khwarizmi

Algorithms: Description

- Algorithms are the problem solving steps in our mind!!!
- How can we document it (don't forget it)?
- How can we explain/teach it to others peoples?
- How can we explain it to computers?
- We need some methods to describe algorithms!
  - **Flowcharts**
  - **Pseudo-codes**
  - **Codes / Programs**

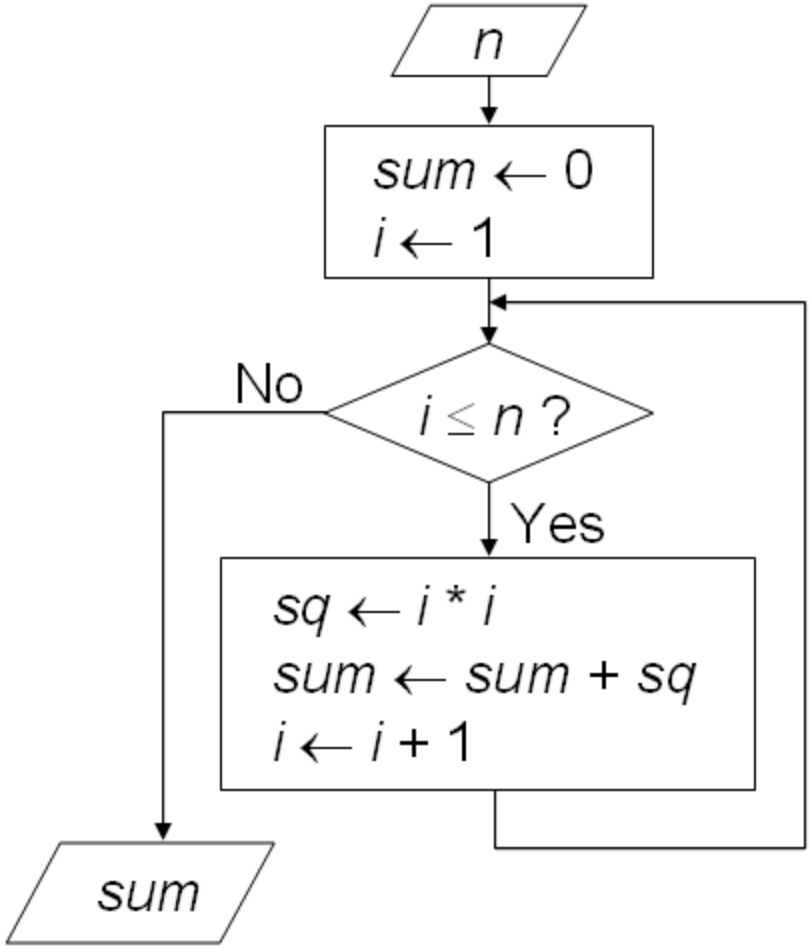
Algorithms: Description (cont'd)

- Flowcharts:
  - Schematic representation



- Example:

calculate $1^2 + 2^2 + \ldots + n^2$



Algorithms: Description (cont'd)

- Pseudo-code
  - A sequence of English and mathematical statements

Algorithm: calculate $1^2 + 2^2 + \ldots + n^2$

Input: n

Output: sum

sum ← 0

i ← 1

Repeat the following three steps while i ≤ n:

sq ← i * i

sum ← sum + sq

i ← i + 1

Algorithms: Description (cont'd)

- Flowcharts and Pseudo-code are for humans not for computer
  - Computer cannot run them
- What can computer run?
  - Instructions in main memory
  - The instructions are in "011100001…" format
  - To use computers
    - We should describe your algorithm in "01" format
  - ????? ☹ ☹

What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems

Programming Language

- Programming languages are the tools to describe your algorithms for computers
  - Software is developed by programming languages
- New languages which is understandable by computers
- Human languages are not used. Why?
- When algorithm is described with a programming language
  - It cannot be run on computer directly if the languages is not 011001001 ☹
  - There are some other programs that translate the programming language to “010…”
  - The output “0101…” can run on computers ☺☺

Programming Language: Machine Level

- Computer's native language
- What is saved in the main memory
- The processor architecture specifies the format of 01s, machine depended
- Example
  - Add two numbers: `00100111 1010 0101`
- Completely incomprehensible to (most) people

Programming Language: Assembly

- Programming based on *mnemonics*
- There are one-to-one mapping between machine language and assembly mnemonics

Assembly Language	Machine Language
LOAD	100100
STOR	100010
MULT	100110
ADD	100101
SUB	100011

- Example

```
load   r1, [4000]  ; read content of address 4000
add    r1, 1       ; add 1 to CPU register r1
store  [5000], r1  ; save the result in location 5000
```

Programming Language: High Level

- Easy for programming, English-like keywords
  - More similar to natural languages
- There isn't one-to-one relation between high level statements and machine level statements
- Example: **C**, **C++**, Pascal, Java, PHP, Python,…
- Example:

```
int xyz;
int abc;
abc = xyz + 1;
```

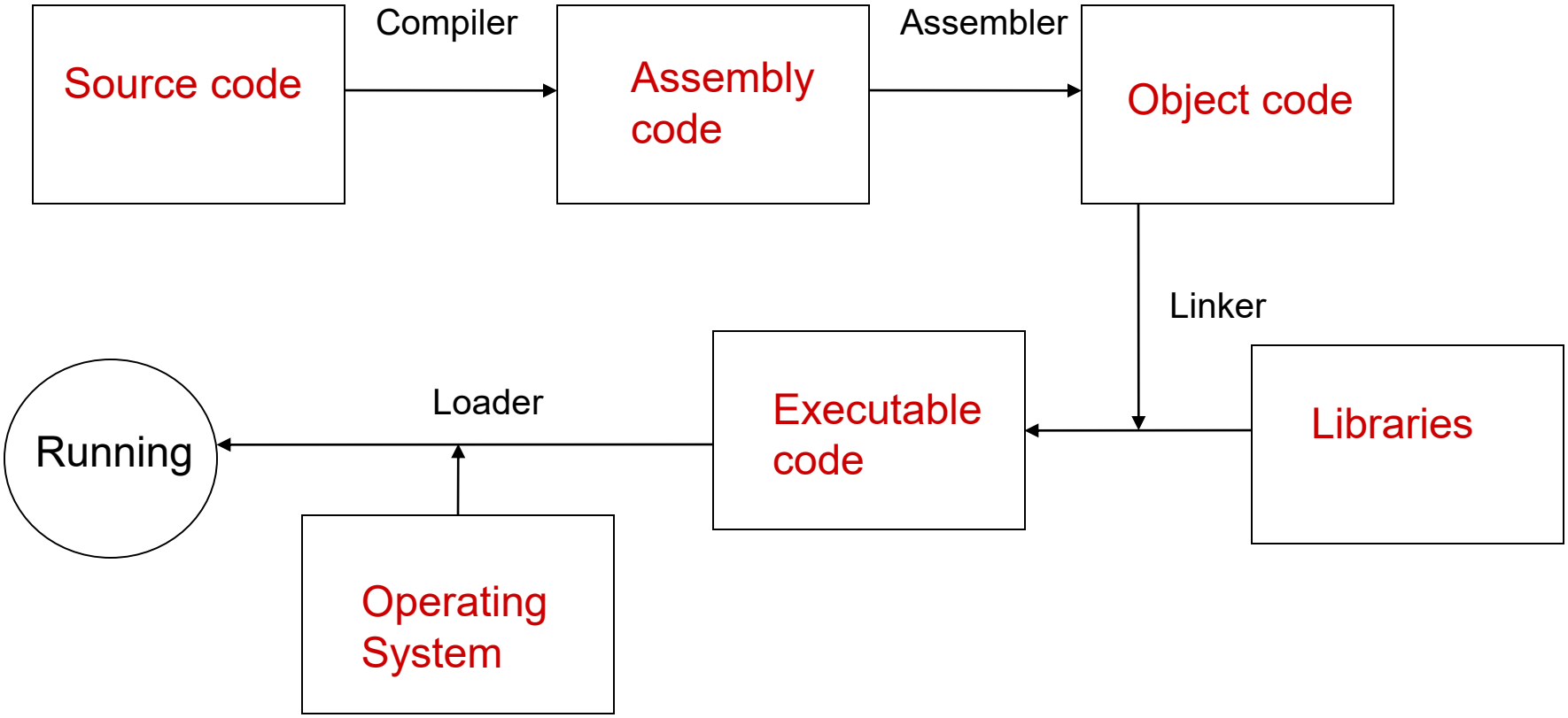
Translation of High Level Languages

- Two types of translators
  - Interpreter (مفسر)
  - Compiler (مترجم)
- Interpreter
  - Checks and runs program lines one-by-one
  - Easy, slow, and we need the interpreter
- Compiler
  - Check all lines, creates executable output file
  - Fast and Stand alone program

Compiler

- Compiler
  - A set of computer programs do the Compilation
  - Preprocessor: Prepare file for compiler
  - Compiler: Create assembly code
  - Assembler: Convert assembly code to binary code
  - Linker: Collect all required binary files (from libraries) into a single loadable file
  - Each language has its own compiler
- Usually compiler do all above steps, you just compile the file and get a executable file

Building & Running Program



What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems *using computers*

Solving Problems

- How to solve problems using computers
  - Develop a program for it
- Steps
  - Analysis: Input, output
  - Algorithm Design
  - Coding
  - Compile → program
  - Execution → test
  - Documentation

Solving Problems: Analysis

- Problem solving process consists of

  Input → **Algorithm** → Output

- Determine what information is available as the input to your algorithm
- Determine what information is desired as the output from your algorithm
- What needs to be done on the input to produce the output? **Algorithm**

Solving Problems: Algorithm

- Determine a series of steps that transforms the input data into the output results
  - Find a solution
  - Break down the steps
- Find all the special cases that the must be handled
- If necessary modify or redesign your series of steps so that all special cases are handled
- Verify (**test**) your algorithm

Solving Problems: Coding

- Describe your algorithm by a programming language
- You must code exactly in the programming language syntax
- Compiler itself is a program it isn't a human
  - It is not intelligent
  - It just does the steps of the compiling algorithm
  - It does not understand what do you mean!!!

Solving Program: Execution

- Compiler generated the executable file
- Run the executable code
  - First try to use simple
    - Give the input
    - Get results
  - Then try larger and complex inputs

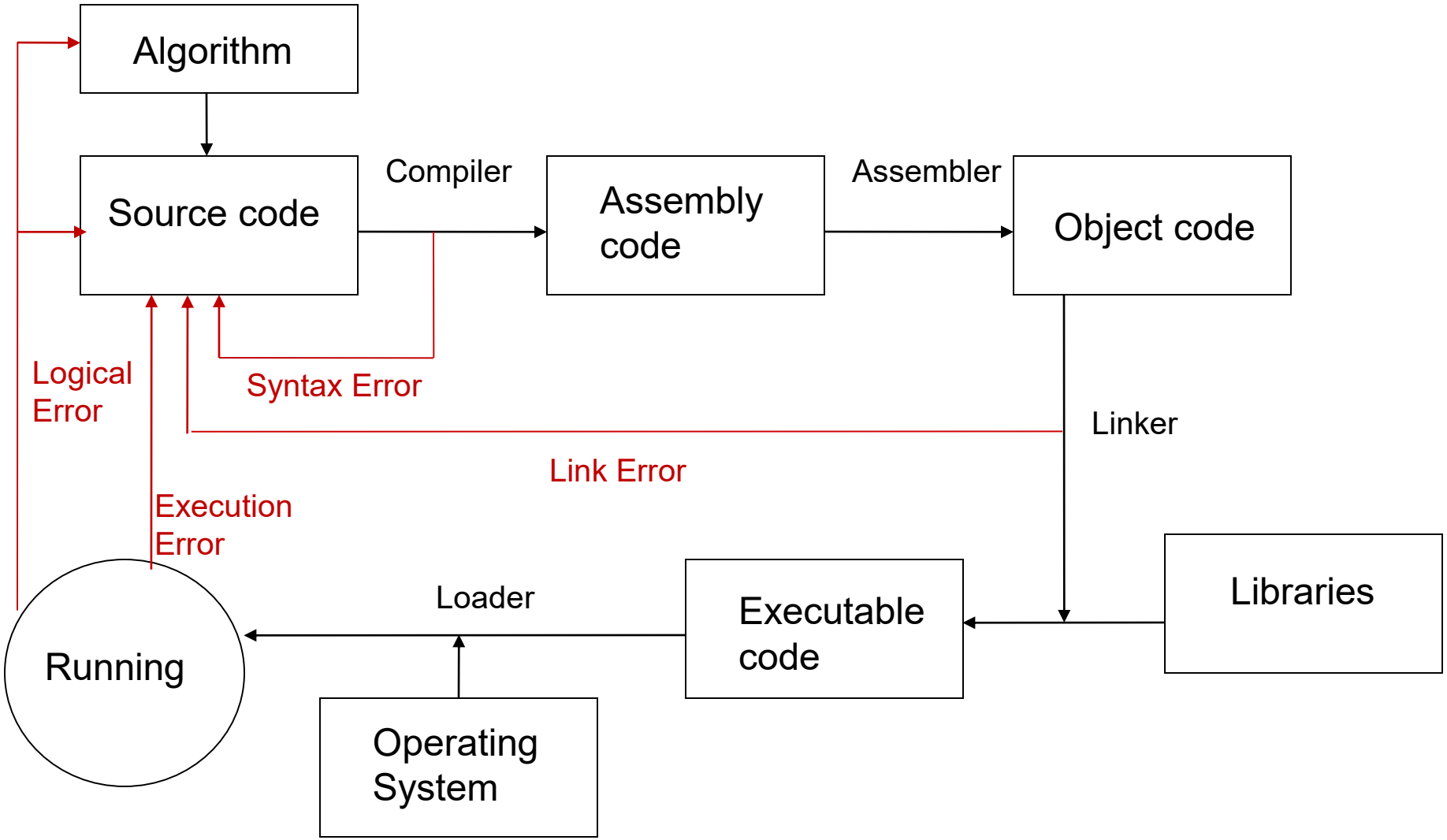
Errors in Solving Problems

- Compile / Syntax error: Compiler does not recognize your code
- Link error: Linker cannot find the required libraries
- Runtime error: Program does not run correctly
  - Example: Division by zero
- Logical Error: Program does not produce the expected result
  - It is called bug
  - No one (compiler, assembler) except debugger can help you ☹
- Why error?
  - You do not understand and analysis the problem correctly
  - You do not develop a right algorithm for the problem
  - You have mistakes in your coding

Debugging

- The process of resolving the errors
  - Example: A program to divide two numbers
- Compile/Syntax error
  - Compiler tells where it is → check syntax
- Link error
  - Compiler tells what it is → check syntax & libraries
- Run time error
  - Try to find it → use debugger to run step-by-step, print debug messages
  - Check syntax & semantic of the line
- Logical error
  - Try to find it → use debugger to run step-by-step, print debug messages
  - Check syntax & semantic of program
  - Revise the algorithm

Building & Running Program



Desired Features of Programs

- Integrity (درستی)
  - Correctly solve the problem
- Clarity (وضوح)
  - Easy to read
- Simplicity (سادگی)
  - Easy to understand
- Efficiency (کارایی)
  - Speed and memory
- Modularity (پیمانه‌ای)
  - Break down of a large task
- Generality (عمومیت)
  - Tunable by input as much as possible

Summary

- Computer organization
  - Hardware and Software
- Algorithm & Program
  - What is the difference between them
- How to solve a problem using computer
  - Steps
- Errors in problem solving
- What is the next: Design algorithm → Program

Reference

- Reading Assignment: Chapter 1 of “C How to Program”